BEAM PIPE DESORPTION RATE IN RHIC *

H. Huang, W. Fischer, P. He, H. C. Hseuh, U. Iriso, V. Ptitsyn, D. Trbojevic, J. Wei, S.Y. Zhang,
BNL, Upton, USA

Abstract

In the past, an increase of beam intensity in RHIC has caused several decades of pressure rises in the warm sections during operation. This has been a major factor limiting the RHIC luminosity. About 430 meters of NEG coated beam pipes have been installed in the warm sections to ameliorate this problem. Beam ion induced desorption is one possible cause of pressure rises. A series beam studies in RHIC has been dedicated to estimate the desorption rate of various beam pipes (regular and NEG coated) at various warm sections. Correctors were used to generate local beam losses and consequently local pressure rises. The experimental results are presented and analyzed in this paper.

INTRODUCTION

The Relativistic Heavy Ion Collider (RHIC) consists of two rings named as blue and yellow rings, respectively. There are six interaction regions named as 2 to 12 o'clock. RHIC is a very flexible collider, which can collide beam at various energies with various species. It has collided various ions (Au-Au, d-Au, pp, and Cu-Cu so far). It has collided Au-Au beam at 67GeV and 100GeV, while collided polarized protons at 31GeV, 100GeV and also 204.9GeV. A sketch of the RHIC accelerator complex is shown in Figure 1.

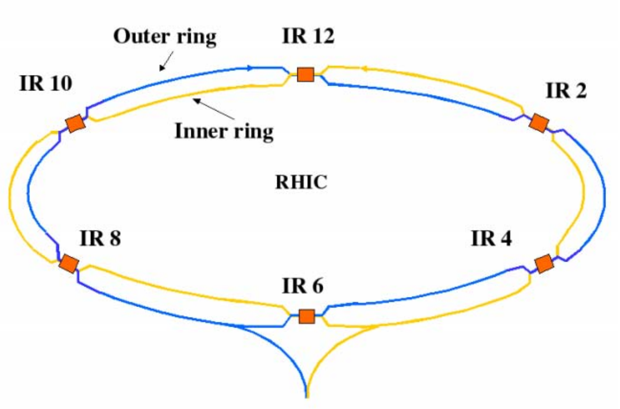

Figure 1: Sketch of RHIC. There are six IRs and they are named as 2 to 12 o'clock. There area total about 700 meters warm straight sections.

The beam intensity in RHIC is limited due to the pressure rise encountered. A several decades pressure rise was observed at RHIC injection during the Au-Au run-2. The pressure rise is not evenly distributed, but happens mostly at warm sections and IRs. The pressure rise patterns are different for gold and proton beams and they are also different for different injection patterns (55 vs. 110 bunches). The beam injection pressure rise caused vacuum valve closures and beam aborts as shown in Fig. 2, limiting the beam intensity [1,2]. It is suspected to be due to molecular desorption, mainly sustained by electron multipacting, but other causes may exist such as ion desorption or beam losses.

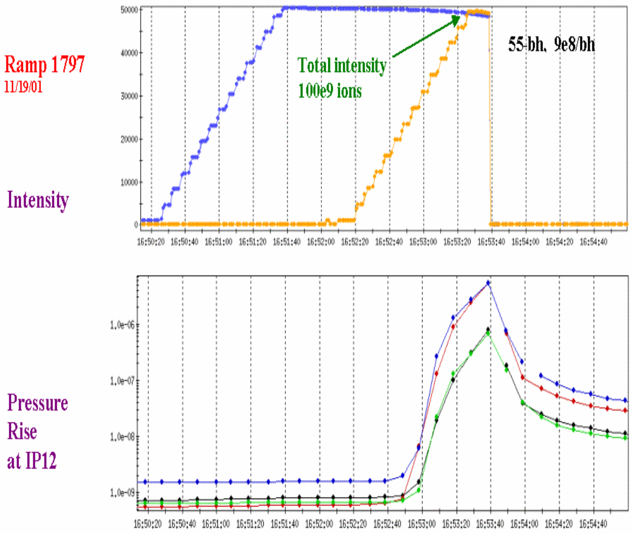

Figure 2: An example of significant pressure rise during run2 . The pressure rise was as high as 5×10^{-6} Torr and caused beam dump.

Many other studies related to counter measures have been performed in the past a few years. Among them are beam scrubbing, beam gap and beam pattern effects; solenoid effects and beam momentum spread effects at transition [3-4]. One important counter measures is the non-evaporable getter (NEG) coated pipes. They were installed before run4 in some warm sections of RHIC for testing. The 50 meter NEG pipes are distributed in several straight sections. The desorption rate in the warm sections with and without NEG pipes are measured and used to evaluate the effect of NEG pipe installation. These desorption rates themselves are also important physics results. The ion desorption has been extensively studied in RHIC for two reasons. First, a possible large ion

---

*Work performed under Contract No. DE-AC02-98CH1-886 with the auspices of the DOE of United States, and with support of RIKEN (Japan).

desorption rate may be directly responsible for certain types of pressure rise. Second, the secondary particles created after beam loss may lower the electron cloud threshold. There have been other desorption rate measurements with perpendicular injected beam. However, the desorption rates are sensitive to the incident angle. We are interested in the desorption rate with shallow incident angles.

DESORPTION RATE

During beam studies and operations, the pressures in the vicinity of the NEG pipes were always low. However, the contribution of the pumping cannot be identified and separated from other mechanisms. It was expected that by steering beam to beam pipe, the observed pressure rise may be used to estimate the desorption rate of lost gold ions. Also, high pressure rise may come along with massive secondary activities (electrons, ions, and gas molecules), and then electrons may be detected by the electron detectors.

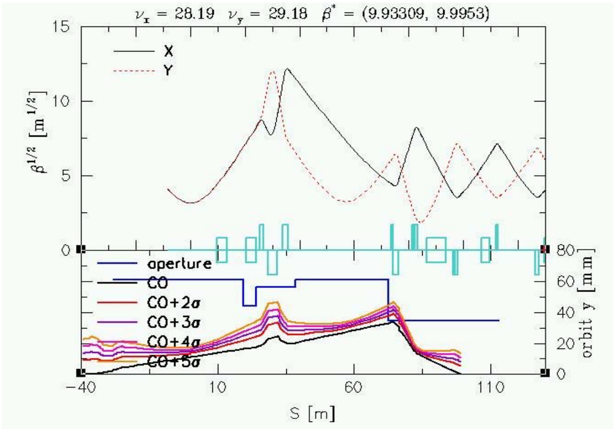

Figure 3: RHIC lattice around the location of the experiments. Top plot shows the beta functions around the IR (S=0m). The middle plot gives the magnets (half rectangular represents dipole and full rectangular represents quad). The bottom shows the traces of particle in the center and with several different rms beam sizes along with the beam pipe.

The ion desorption effect was studied by creating beam scraping at the warm straight sections, either using a dipole to control the local beam loss, or simply using a dipole to steer and dump a few bunches of beam at different locations. There are three vacuum gauges in the warm sections: one in the middle of the warm section (so called PW2), the other two locate at the two ends of the warm sections (so-called PW1 and PW3, about 35m and 70m away from IP, respectively). There is an ion pump next to each vacuum gauge. The beam intensity and pressure rises at all these three gauges are recorded. With vacuum pumps on, the desorption rate η can be calculated approximately from following formula:

$$\eta = G\Delta P\Delta t S_{eff} /(2N) \qquad (1)$$

where G=3.54×10^{19} [Torr*l/molecules] at 0°C, S_{eff} is pumping speed [l/s], ΔP is pressure rise [Torr], Δt is time of pumping down, and N is the number of impacting ions. Figs. 4 and 5 give the examples of the single turn kick results for BO11 and YO12 warm sections.

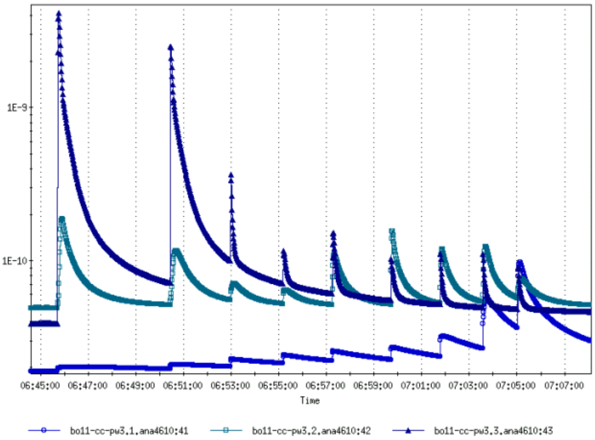

Figure 4: Ion desorption measurement in Blue ring. Horizontal axis is time and vertical axis is the pressure. About 3×10^{9} gold ions at 9.8GeV/u dumped in two straight sections with incident angles 1 to 2 mrad. On the left side of the plot, at about 3.2 mrad, ion desorption rates are 10^{6} to 10^{7}.

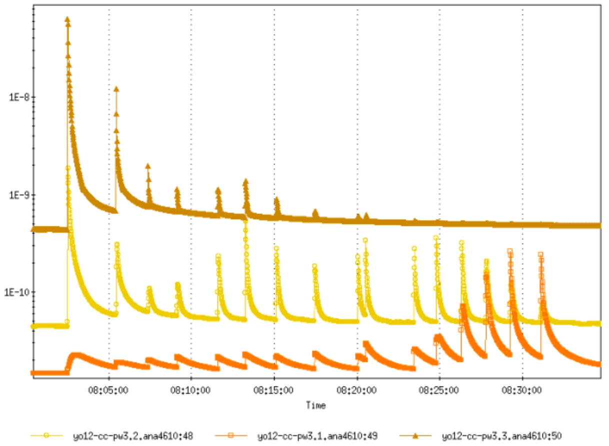

Figure 5: Ion desorption measurement in Yellow ring. About 3×10^{9} gold ions at 9.8GeV/u dumped in two straight sections with incident angles 1 to 2 mrad. On the left side of the plot, at about 3.2 mrad, ion desorption rates are 10^{6} to 10^{7}.

In both single turn kick and scraping cases, the ion desorption rate of incident angles from 1 to 3 mrad is about 2×10^4 molecules. Nevertheless, in both studies, some irregular cases were found showing much higher desorption rates. For example, in Fig. 6, a desorption rate of 1.3×10^7 is shown. Comparable test results were also obtained with proton beams. It is suspected that in these incidents a part of the beam particles may actually be executing halo-like scraping at much smaller angles, giving rise to the high yield. This speculation is consistent with studies using the collimator scraper. Normally, little or no pressure rise is produced in the beam collimation, but sometimes, very high desorption rates are observed. The desorption rate in yo12 is also systematically higher than bo11 section. Since the polarimeter is in yo12 and the target chamber has to be opened every year, the surface quality of nearby beam pipe is worse than that of bo11.

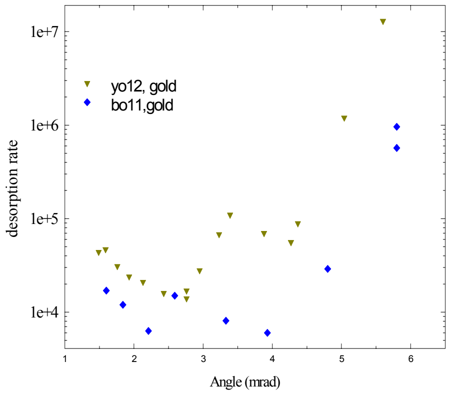

Figure 6: The desorption rate of warm sections of yo12 and bo11 based on experimental data shown on Figs. 4 and 5.

NEG BEAM PIPE

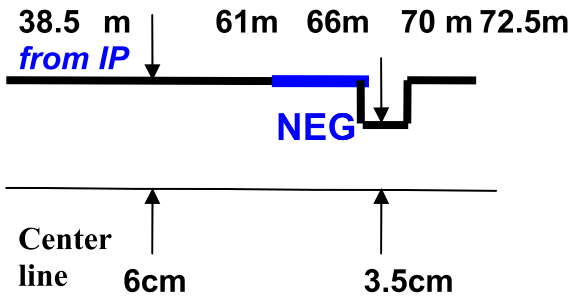

Figure 7: The beam pipe in bo2 section(blue ring near 2 o'clock).

The expected properties of NEG coating include a reduced secondary electron yield, a low electron impact molecular desorption rate, possible lower ion desorption rate, and additional pumping after activation. In the presence of NEG pipe, Eq. (1) gives the effective desorption rate (i.e., the rate reduced by NEG pumping). The desorption rate was evaluated by comparison between NEG pipe and regular pipes. By varying the single turn kick strength, the beam can be steered to the beam pipe with or without NEG coating.

Table 1: The ion desorption rate at NEG coating is a factor 2 to 3 less than the ones of stainless steel

Distance	Desorption rate	Conditions
67.1m	2810	~90°
65.1m	4460	NEG
63.5m	4300	NEG
59.4m	8450	Regular
59.1m	10900	Regular
59.0m	16000	Regular
57.6m	17600	Regular
56.6	11400	Regular

For cases with 63.5m with ~59m, other conditions are similar (distance from pump, gauge, pipe radius) except NEG and regular pipes. The desorption rate is clearly different. This result is obtained excluding the factors of NEG pumping, and in agreement with Ref. [5].

CONCLUSIONS

The desorption rate was measured for RHIC beam pipe, in the order of 10^4 for regular pipe. The typical desorption rates for the regular pipes are similar from the two different methods (e.g., bi12: $\sim3.5\times10^4$ with warm dipole and $\sim4.5\times10^4$ for single turn kick). The desorption rate for NEG pipe are 2~3 times smaller (compare NEG pipes with nearby non-NEG pipes in yi10 and bo2). The NEG pipe clear showed better vacuum performance. The typical desorption rates for angles range around 1-3 mrad are $10^{4\text{-}5}$. The desorption rate was in the order of 10^4 for regular pipe and the numbers for NEG pipe are 2~3 times smaller. Based on this and other experiments, more NEG pipes were installed in RHIC warm sections and clearly resulted higher beam intensity reached in recent RHIC operations[6-7].

REFERENCES

[1] S.Y. Zhang, *et al.*, Proc. of PAC03, p. 54.
[2] W. Fischer, *et al.*, Proc. ECLOUD'04, (2004).
[3] S.Y. Zhang, H. Huang, W. Fischer, and T. Roser, Proc. of EPAC04, p. 947.
[4] U. Iriso, *et al.*, Proc. of EPAC04, p. 2239.
[5] P. Thieberger, *et al.*, these proceedings.
[6] S.Y. Zhang, *et al.*, Proc. these proceedings.
[7] V. Ptittsyn, *et al.*, these proceedings.